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Moving U.S. Climate Policy Forward

Are Carbon Taxes the Only Good Alternative?

Ian W.H. Parry and Roberton C. Williams III

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1616 P St. NW
Washington, DC 20036
202-328-5000 www.rff.org

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Abstract

This paper estimates the welfare costs of the main medium-term options for significantly reducing U.S. energy-related carbon dioxide (CO_2) emissions, including carbon taxes and cap-and-trade systems applied economy-wide and to the power sector only, and an emissions rate standard for power generation. The key theme is that welfare costs depend importantly on how policies interact with distortions in the economy created by the broader fiscal system.

If allowance rent is not used to increase economic efficiency, economy-wide cap-and-trade systems perform the worst on cost-effectiveness grounds. In contrast, if revenues are used to substitute for distortionary income taxes (either directly, or indirectly through deficit reduction), economy-wide carbon taxes (or auctioned allowance systems) may have (slightly) negative costs. The bottom line is that revenues or rents created under economy-wide, market-based carbon policies must be used to increase economic efficiency to ensure that these instruments are more cost-effective than regulatory or sectoral approaches.

Key Words: carbon tax, cap-and-trade, cost-effectiveness, distortionary taxes, revenue recycling

JEL Classification Numbers: Q48, Q58, H21, R48

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1. Introduction

The recent failure of the U.S. Congress to pass a comprehensive climate bill, with cap-and-trade as the jewel in the crown, provides an opportune time to return to basics and reevaluate the main options for moving U.S. climate policy forward. These options might be classified into three broad groups, at least if we limit discussion to practical policies that potentially yield large economy-wide emissions reductions.[1]

First is some form of cap-and-trade policy, though perhaps less ambitious in both scale and scope (e.g., a cap-and-trade program applied only to the power sector). Second is its market-based rival, namely a carbon tax, which we take to mean a tax on the carbon dioxide (CO_2) potential of fossil fuels. Although previously viewed as a political nonstarter, this option may receive serious attention when U.S. policymakers consider fundamental tax reforms to address the structural budget deficit. And third are the regulatory alternatives, the most promising of which is an emissions rate standard for (new and existing) power generation sources. Regulatory approaches can avoid large increases in energy prices because they do not involve tax payments or allowance rents, which are passed forward into higher prices under market-based approaches.

In evaluating these alternatives, practical feasibility is clearly a concern, though even political scientists are skating on thin ice when trying to predict what climate policies may or may not be politically viable a few years down the road. This paper sticks to the economist's home turf—that is, the costs and overall net economic benefits of the alternatives and the

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* Ian Parry is the Allen V. Kneese Senior Fellow at Resources for the Future (RFF). Roberton Williams is a professor at the University of Maryland and a senior fellow at RFF. We are grateful to Kenneth Richards, Gerhard Glomm, and seminar participants at the University of Manchester, Resources for the Future, University of Indiana, and the Fiscal Affairs Department, International Monetary Fund, for helpful comments on the paper.

[1] In the meantime, the U.S. Environmental Protection Agency will regulate CO_2 emissions on a piecemeal basis under the Clean Air Act. EPA has already set standards for CO_2 emissions per mile for new passenger vehicles and is also considering regulation of new stationary emissions sources (and those undergoing major upgrades), but how this ultimately will be implemented is still uncertain. There is even greater uncertainty about how EPA would regulate other existing stationary emissions sources.

efficiency-feasibility trade-offs. For reasons noted below, we focus on policies to reduce domestic, energy-related CO_2 emissions.

The “standard” approach to assessing the welfare costs of climate policies would involve the quantifying distortions they introduce in fuel and energy markets. This approach would yield the usual assertion that market-based approaches, at least those with broad coverage, are superior on cost-effectiveness grounds to regulatory approaches. The logic sounds compelling. By placing a price on emissions, market-based approaches automatically equalize the marginal costs of abatement across all emissions control options. In contrast, an emissions standard for the power sector (achieving comparable economy-wide CO_2 reductions) places too much burden on reducing the emissions intensity of that sector, and too little (or no) burden on other abatement opportunities, such as energy conservation or reductions from transport and industry. So market-based approaches constitute the best alternatives for initiating a nationwide climate policy, right?

Not necessarily, because the standard approach fails to account for how policies interact with preexisting sources of distortion in the economy created by other policy interventions or market failures. It has long been recognized in public finance that these interactions must be taken into account in order to obtain unbiased measures of welfare cost (e.g., Lipsey and Lancaster 1956; Harberger 1964).

In fact, building off work on green tax shifts, researchers have demonstrated that distortions in the economy created by the broader fiscal system can have important implications for environmental policy instrument choice.[2] One finding from the literature is that the costs of emissions taxes (or their auctioned cap-and-trade equivalent) can be reduced, quite substantially, when revenues finance reductions in income, payroll, and other taxes that distort factor markets. Another finding is that the costs of market-based approaches that do not exploit the revenue-recycling benefit can, under certain circumstances, exceed those of regulatory approaches. This is because the larger increase in energy prices caused by market-based policies leads to a relatively large source of additional efficiency loss, as higher product prices throughout the

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[2] For earlier work on green tax shifts see, for example, Sandmo (1975), Bovenberg and de Mooij (1994), Bovenberg and van der Ploeg (1994), Goulder (1995), Parry (1995), and Schöb (1997). Studies of the implications of prior tax distortions for environmental policy instrument choice include Goulder et al. (1999) and Fullerton and Metcalf (2001).

economy reduce the real returns to factors of production, thereby compounding factor tax distortions.

This essay discusses the implications of this literature for the choice of climate policy instrument, given the proposed scale of CO_2 reductions envisioned for the United States over the next decade or so. To do this, we use a highly simplified analytical framework, where the impact of (future) CO_2 pricing on various emissions sources is chosen to be consistent with recent policy simulations from a detailed model of the U.S. energy sector. We begin in the next section by discussing the costs of economy-wide, and electricity-only, CO_2 pricing instruments, as well as those of emissions standards, according to the standard approach.

Section 3 discusses additional welfare effects due to interactions between climate policies and prior tax distortions. According to these estimates, economy-wide carbon taxes (or their auctioned permit equivalent) are easily the best instrument, generating large overall welfare gains so long as revenues are used to substitute for distortionary taxes (either directly or indirectly, through reducing the need to raise revenues from other taxes to meet deficit reduction goals). In contrast, if revenues or rents from economy-wide pricing policies are not used to increase efficiency—as was generally the case in proposed federal cap-and-trade legislation—they are the worst-performing instrument on cost-effectiveness grounds and generate large overall welfare losses under plausible assumptions about the social cost of carbon. Electricity-only policies, and emissions standards, are intermediate cases, though their welfare potential is well below that of the revenue-neutral carbon tax.

Section 4 discusses considerations that might change our assessment of welfare effects: more stringent emissions control scenarios, difficulties in accurately measuring fiscal linkages, alternative assumptions about behavioral responses to emissions pricing, policy-induced technological innovation, ancillary externality benefits, distributional considerations, and the effect of U.S. action on international emissions-control agreements. Despite these considerations, and with the usual caveats that parameter assessments might change in light of future evidence, it is still hard to escape the general conclusion that carbon taxes (or auctioned permits), with revenues substituting for other distortionary taxes, might be the only economically sound instrument for achieving medium-term targets for U.S. CO_2 reductions.

In fact, the stars might just be aligning in favor of this policy. A serious, economy-wide program to price CO_2 emissions in the United States is long overdue, not just for its own sake, but also for reinvigorating negotiations over international emissions control agreements. The political momentum for cap-and-trade in the United States has stalled, not least because of intense competition for the distribution of valuable allowances. On the other hand, a carbon tax of the scale discussed here, with revenues accruing to the U.S. Treasury, would not only achieve climate objectives but could also plug about a third of the projected deficit in the nation's public finances out to 2030 (see Figure 1), reducing the inevitable need, sooner or later, for other tax increases.[3]

2. The Standard Approach to Measuring Climate Policy Costs

Conceptual Approach

We start by considering policies imposed upstream in the fossil fuel supply chain and then discuss sector-specific policies. Throughout, we use a deterministic analysis where carbon taxes and cap-and-trade systems with full allowance auctions are essentially equivalent instruments.[4] Our main focus is on the gross costs of CO_2 policies, given the contentious nature of valuing global warming damages, though later we present some calculations of net benefits.

Taxing the carbon content of fossil fuels causes a variety of price changes throughout the economy, leading to various behavioral responses and sources of welfare loss in markets directly affected by the tax.

Consider the gasoline market, as depicted in long-run equilibrium in Figure 2(a), where imposition of the carbon tax (or equivalently, a cap-and-trade system) reduces gasoline consumption and drives a tax wedge between the demand price and supply price equal to the carbon tax times the carbon content of gasoline (the implications of prior fuel taxes are discussed in Section 4). The shaded triangle reflects the deadweight loss in the gasoline market caused by the carbon tax, which can be interpreted as the loss of benefits to fuel users (the relevant area

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[3] For a discussion of why the federal budget deficit needs to be addressed at some point, see Auerbach and Gale (2010). In fact, these authors suggest that the budget outlook may be significantly more dire than indicated in Figure 1.

[4] There is an extensive literature on the additional costs under pure cap-and-trade systems due to year-to-year uncertainty over marginal abatement cost schedules (e.g., caused by fuel price volatility). Such variability causes (discounted) marginal abatement costs to differ over time under a fixed cap, compared with carbon tax regimes, where marginal costs are fixed by the tax rate. In Fell et al. (2008), for example, this intertemporal inefficiency raises the cost of cap-and-trade by around 15 percent. However, there are various mechanisms to reduce marginal cost variability under cap-and-trade programs, including price collars and allowance banking and borrowing provisions.

under the demand curve) less savings in producer costs (the relevant area under the supply curve), or alternatively, the loss of consumer and producer surplus, less tax revenue to the government (or rent accruals to those receiving allowances under cap-and-trade). The MC^G curve in Figure 2(c) shows the marginal abatement cost schedule for reducing emissions from gasoline use. For a given carbon tax rate t^C, the area under this curve corresponds to the shaded triangle in 2(a), where the CO_2 emissions reduction, denoted ΔZ^G, is the reduction in fuel use times CO_2 per gallon of fuel.

Next, consider the electricity market, as shown in Figure 2(b), where electricity use falls in response to the carbon tax. There are two components to the increase in electricity price. First is the increase in per unit production costs as generators switch from carbon-intensive fuels (such as coal) toward zero- or low-carbon but more costly fuels (such as nuclear, renewables, and natural gas); the fuel switching reduces the emissions intensity of production. Second is the tax paid on the remaining emissions per unit of production. The welfare cost of the tax consists of the shaded triangle in Figure 2(b), reflecting forgone benefits to electricity users net of savings in production costs, and the shaded rectangle, reflecting higher resource costs involved in producing the ex post output level (the tax payment is a transfer, not a welfare cost). MC^E in Figure 2(c) is the marginal cost from reductions in power sector emissions. For the emissions tax t^C, the area under MC^E corresponds to the sum of the shaded areas in Figure 2(b), where the emissions reduction ΔZ^E reflects both reduced electricity consumption and reduced carbon intensity of generation.[5]

Also shown in Figure 2(c) is MC^O, the marginal cost of reducing CO_2 from all other (energy-related) sources, such as direct industrial and household fossil fuel use and nonautomobile travel: these emissions fall by ΔZ^O. MC^{ALL} is the envelope of all the marginal costs, where emissions fall by $\Delta Z = \Delta Z^G + \Delta Z^E + \Delta Z^O$ under the tax of t^C per ton of CO_2.

We take all the marginal cost curves as linear over the relevant range, which should be a reasonable ballpark assumption for the scale of emissions reductions considered here. According

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[5] Note that the MC^G and MC^E curves capture costs from a mixture of short-run behavioral responses, like reductions in driving, and investment behaviors, like adoption of energy-saving technologies or construction of wind farms. Implicitly, the net costs of these investments—the upfront cost of technology adoption net of the discounted flow of energy savings or revenues from energy sales—are expressed on an annualized basis (i.e., net costs are apportioned over the life of the investment).

to the standard approach, the overall welfare cost of the carbon tax is the relevant area under the MC^{ALL} curve, or $(1/2)\cdot t^C \cdot \Delta Z$ (ignore the shaded rectangle in Figure 2(c) for now).

Suppose instead the same emissions reduction, ΔZ, was obtained by a carbon policy applied to all power generators in a downstream program that priced emissions at the point of fuel combustion. In this case, the cost of the policy is given by the relevant area under the MC^E curve in Figure 2(c). By similar triangles, the slope of this curve is equal to $\Delta Z / \Delta Z^E$ times the slope of the MC^{ALL} curve.

Alternatively, consider an emissions standard for the power sector where all generators are subject to a maximum allowable rate of CO_2 emissions per kWh. Also suppose that the regulation is "smart," in terms of allowing full trading of compliance credits. Thus, generators with a high-carbon fuel mix will purchase credits from generators with a low-carbon fuel mix. This policy promotes fuel switching just as a carbon pricing policy does. However, it avoids a large transfer of tax revenue to the government, or the creation of allowance rent, which is the main cause of higher energy prices and reduced electricity demand under a carbon tax or cap-and-trade system. Firms simply have to lower their average emissions rate; they do not have to pay taxes on, or buy allowances to cover, their remaining emissions.[6] Assuming the policy has a minor effect on electricity demand, and following the same logic as above, we could trace out a marginal cost curve for this policy, whose slope would equal the slope of the MC^{ALL} curve divided by the share of economy-wide emissions reductions (under economy-wide emissions pricing) that come from fuel switching in the power sector.

Initial Welfare Cost Calculations

Table 1 summarizes data assumptions used here and below in our assessment of policy costs. We focus on the projected reduction in domestic, energy-related CO_2 emissions for year 2020 that might have been forthcoming under recent federal legislation. Emissions reductions and prices under this legislation are taken from Krupnick et al. (2010, Ch. 6.1), who in turn

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[6] Since there is no cap on total emissions, there is no creation of scarcity rents under an emissions standard. The policy is similar to a clean energy portfolio standard where fuels with low or zero carbon content receive partial or full credits, respectively, in enabling the generator to comply with the standard. For more discussion, see Palmer et al. (2010).

derived them from simulations of a variant of the Department of Energy's National Energy Modeling System (NEMS).[7]

Recent federal climate bills have sought to reduce greenhouse gases (GHGs) primarily through an economy-wide cap-and-trade system. For example, H.R. 2454, the American Clean Energy and Security Act sponsored by Reps. Waxman and Markey, proposed reducing GHGs by 17 percent below 2005 levels by 2020 and 42 percent by 2030. However, much of these reductions could be (nominally) achieved through domestic and international offset programs (e.g., U.S. firms would pay for forest preservation in Brazil in lieu of making cuts in domestic energy-related CO_2). Under an intermediate assumption about achievable (domestic and international) emissions offsets, Krupnick et al. (2010) project that CO_2 emissions would be reduced from 5.88 billion tons in 2020 to 5.38 billion tons under the Waxman-Markey bill, or 8.5 percent. The associated price of CO_2 for this reduction in 2020 is $33 per ton (in 2007 dollars).[8]

In this policy simulation, CO_2 emissions reductions from reduced electricity demand and fuel switching in the power sector account for 21 and 68 percent of economy-wide CO_2 reductions, respectively. So overall, the power sector accounts for 89 percent of economy-wide reductions. Emissions reductions from transportation account for only 5 percent of economy-wide reductions. This reflects the modest effect of carbon pricing on transportation fuel prices, the presence of preexisting, binding fuel economy regulations that greatly reduce the effects of higher fuel prices on vehicle fuel economy, and the general lack of low-carbon alternatives to oil-based transportation fuels. The remaining 6 percent of reductions is from other sources, like

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[7] Projections from the NEMS are widely used in other energy models. Krupnick et al. (2010) made adjustments to the NEMS model to reflect expert judgment on the prospects for nuclear power to expand in response to carbon pricing (emissions price projections are not very sensitive to enhanced availability of natural gas shale). Not all the figures cited here are reported in Krupnick et al. (2010); some are obtained from spreadsheets containing the outputs of model runs.

CO_2 emissions are proportional to the carbon content of fossil fuels in these runs, so an upstream carbon pricing policy does not need to be supplemented with a downstream system of credits for carbon capture and storage. In Krupnick et al. (2010), carbon capture and storage technologies do not become commercially viable under carbon pricing until well after 2020.

[8] Despite the large potential for sequestering CO_2 in forests at relatively low cost, carbon offsets are contentious at present (e.g., Sedjo and Macauley 2010) because of the difficulties of monitoring forest growth, verifying a project's additionality (carbon sequestration beyond what would have occurred without the project), and accounting for leakage (e.g., increased deforestation outside the project area induced by higher global timber prices from slowed deforestation in the project region). For these reasons, Krupnick et al. (2010) assumed that 50 percent of offset provisions would be realized.

direct household and industrial use of fossil fuels (e.g., for space heating and machinery operation).

The first set of rows in Table 2 summarize our benchmark estimates of alternative policy costs, according to the standard approach. In this hypothetical case, where there are no distortions in the economy aside from the carbon externality, use of revenues or rents from pricing instruments is irrelevant. The gross welfare cost of the economy-wide market-based policy is $8.2 billion per year in 2020 (= 0.5 × 0.50 billion tons × 33 per ton), or $16.5 per ton of CO_2 reduced.

From the discussion above, our back-of-the envelope calculation suggests that the costs of a pricing policy affecting CO_2 from the power sector only, but achieving the same 8.5 percent reduction in economy-wide emissions, would be 1/0.89 times as costly as the comprehensive pricing policy, or $18.6 per ton of CO_2 reduced. And with 68 percent of the reduction under an economy-wide carbon pricing policy coming from fuel switching in the power sector, an estimate of the cost of the emissions standard, for the same total emissions reduction, is 1/0.68 times the cost of the carbon pricing policy, or $24.4 per ton of CO_2 reduced in 2020.

Thus, these quick calculations underscore the traditional argument for broad, market-based policies on cost-effectiveness grounds, for the specific amount of abatement considered. However, these cost measures apply only to a hypothetical economy where all markets affected by the CO_2 policy are undistorted by other policies or (noncarbon) market failures. We now discuss various adjustments to these measures that are needed to account for important distortions, beginning with those created by the broader tax system.

3. Accounting for Interactions with the Broader Fiscal System

The implications of factor tax distortions for the cost of environmental policies are the subject of a well-developed literature (e.g., Bovenberg and Goulder 2002). Here we provide a quick summary of the main points. We begin by assuming that the only source of distortion created by the broader tax system is in the labor market. We then consider additional tax distortions and present estimates of costs and net benefits of the various policies.

Tax Distortions in the Labor Market

Figure 3 depicts the (economy-wide) labor market, assuming it is competitive (which is reasonable for the United States). The height of the demand for labor curve reflects the gross wage, equal to the value of the marginal product of labor. This curve is drawn as perfectly elastic, which seems a reasonable long-run approximation when capital is mobile (e.g., Hamermesh 1986). The height of the labor supply curve reflects the net wage, equivalent to the marginal opportunity cost of work effort—that is, the value of time given up in leisure, child-rearing, voluntary activities, and so forth. The supply curve is upward sloping as higher wages encourage, for example, greater labor force participation among secondary workers, additional effort or hours on the job from existing workers, and delayed retirement among senior workers. More generally, higher compensation may increase effective labor supply via greater accumulation of human capital and other skills. Income, payroll, and sales taxes combine to drive a wedge between the gross and net wage, thereby pushing down labor supply below the economically efficient level (where the marginal social benefit and marginal social cost of labor supply would be equated). This causes a deadweight loss indicated by the shaded triangle.

A small increase in the labor tax will further reduce labor supply, resulting in an additional efficiency loss equal to this reduction times the tax wedge (the shaded rectangle in Figure 2(c)). The efficiency cost, expressed per dollar of extra revenue raised, is known as the *marginal excess burden* (MEB) of (labor) taxation.

Revenue-Recycling and Tax-Interaction Effects: Initial Assessment

In Figure 2(c), the amount of revenue raised by the carbon tax (or fully auctioned cap-and-trade system) is given by the rectangle with height equal to the carbon tax and base equal to the remaining emissions $Z^0 - \Delta Z$ (Z^0 is CO_2 emissions in the no-policy baseline). If all this revenue is used to reduce labor income taxes, there is a welfare gain, indicated by the shaded rectangle in Figure 2(c), which should be subtracted from the welfare cost of the carbon policy. This gain, known as the *revenue-recycling effect,* is the MEB times revenue raised from the carbon policy. More generally, if revenues pay down the deficit, they also imply an efficiency gain, albeit a delayed one, because of the reduced need to impose distortionary taxes on future generations.

At the same time, carbon taxes (or allowance prices from upstream cap-and-trade systems) are passed forward into the price of fuels, electricity, and ultimately goods in general, leading to a reduction in the real household wage. This reduces the real returns to work effort and causes the labor supply curve in Figure 3 to shift inward (slightly). The resulting efficiency loss, termed the *tax-interaction effect,* is the labor tax wedge times the labor supply reduction and times 1+MEB to account for the loss of labor tax revenue, which must be made up by an increase in labor taxation (or reduction in public spending).

The literature on carbon taxes in the presence of labor tax distortions generally finds that the cost of the tax-interaction effect exceeds the benefit from the revenue-recycling effect, and therefore the cost of a revenue-neutral carbon tax (or auctioned allowance system) is higher on balance because of interactions with prior tax distortions (e.g., Bovenberg and Goulder 2002; Goulder et al. 1999). This qualitative finding is not surprising. In public finance it has long been recognized that in general (and leaving aside externalities), taxes on inputs like fuels are less efficient at raising revenue than broad taxes on labor income, and therefore, swapping fuel taxes for taxes on work effort will result in positive net costs (e.g., Diamond and Mirrlees 1971).

However, the more important point is that the costs of market-based policies that do not offset the tax-interaction effect with the revenue-recycling benefit—for example, carbon taxes and auctioned cap-and-trade systems with revenues returned to the private sector in lump-sum dividends—can be dramatically higher, particularly for the scale of CO_2 reductions considered here. We will put some numbers on these cost markups in a moment, but first we consider some complications posed by additional distortions from the tax system.

Additional Distortions from the Tax System

Another source of preexisting distortion arises from the taxation of capital. We could draw a similar diagram to that in Figure 3 to represent the capital market, where taxes on corporate income and taxes on personal dividend and capital gains income combine to drive a wedge between the marginal benefit from investment and the marginal cost of saving. In general, the MEB of taxes on capital is thought to exceed that for labor taxes (e.g., Judd 1987). The main point here is that the costs of revenue-neutral carbon taxes or auctioned permits are lower than discussed above if, at the economy-wide level, they cause some shifting of the tax burden off capital and onto labor (e.g., Bovenberg and Goulder 1997). The prospects for this are greater if a disproportionately large share of the revenue is devoted to cutting taxes on capital rather than those on labor, though such a shift may run counter to distributional goals. Conversely, the costs could be higher if the net effect is to shift taxes from labor to capital.

The U.S. tax system also creates a distortion in the pattern of spending across different goods. In particular, tax deductions and exemptions, such as those for owner-occupied housing and employer-provided medical insurance, create a bias toward tax-favored goods away from ordinary (nontax-favored) goods. This means that the MEB of income taxes is greater because higher tax rates not only discourage factor supply but also promote additional substitution toward tax-sheltered goods. In turn, this means that cutting income taxes through the revenue-recycling effect produces larger gains in economic efficiency (than in the absence of tax preferences).[9] On the other hand, the tax-interaction effect is not directly affected, at least if tax-favored and nontax-favored goods have similar energy intensity, in which case higher energy costs have little effect on the relative prices of these goods (e.g., Parry and Bento 2000).

Policy Costs

Rows in the upper third of Table 2 summarize our benchmark estimates of the revenue-recycling and tax-interaction effects and overall costs for different policies and for our assumed level of abatement for 2020 (8.5 percent). These estimates were obtained from spreadsheets developed by Parry and Williams (2010), who examine a similar scenario for emissions reductions and prices in 2020, and additional formulas derived in Goulder et al. (1999). Again, selected assumptions underlying the results are summarized in Table 1.

Market-based, economy-wide policy with the revenue-recycling benefit. Following Parry and Williams (2010), we use a value for the MEB of 0.25 for proportional changes in income taxes (see below for more discussion). A carbon tax of $33 per ton in 2020 raises projected government revenues in that year of $178 billion, given CO_2 emissions with the policy in place are 5.38 billion tons. However, some of this revenue, $29 billion, is needed to index the tax and benefit system in response to higher prices, or looked at another way, revenues have to increase somewhat to maintain a given amount of real public spending. The revenue-recycling effect is therefore $37.4 billion, equal to the MEB times leftover revenues of $149 billion. Note that the revenue-recycling benefit is 4.6 times as large as the cost of the policy as calculated in the standard approach. This follows because the shaded rectangle in Figure 2(c) is large relative to the triangle under the MAC^{ALL} curve, given the assumed scale of emissions reductions.

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[9] In principle, tax preferences are not distortionary if they correct market failures. Our sense from health economists, however, is that the tax exemption for employer-provided medical insurance is more of a historical accident than a benevolent attempt to address inefficiencies in the health care system. And although there might be external benefits to local communities if homeowners take better care of their properties than renters, there are offsetting negative externalities from residential development (e.g., loss of open space and the fiscal burden of additional infrastructure, like roads and schools, that may not be covered by development fees).

The revenue-recycling benefit is only partially offset by the tax-interaction effect, which raises costs by $24.7 billion. Thus, the overall cost of the market-based policy with the revenue-recycling effect is actually negative, at –$4.5 billion, or –$9.1 per ton of CO_2 reduced, even though we have not counted the environmental benefits.

At first glance, it may seem odd that carbon taxes appear to provide a free lunch, but the reason is straightforward. Both carbon taxes (through the tax-interaction effect) and income taxes distort factor supply. Unlike income taxes, carbon taxes also distort fossil fuel markets, but they do not distort the pattern of spending between tax-favored and ordinary goods. Up to a point, the latter advantage of carbon taxes outweighs the former disadvantage, and hence swapping income taxes for carbon taxes lowers the overall costs of the tax system. (This result would go away if inefficient tax preferences were phased out.)

Market-based, economy-wide policy with revenues or rents returned lump sum. An even more striking finding relates to the cost of a carbon tax or auctioned permit system with all the revenues or allowances allocated in lump-sum transfers (or other spending that does not increase efficiency).

This policy does not generate the revenue-recycling effect. In fact, the need to raise revenue (of $29 billion) through distortionary taxes to index the tax and benefit system causes an estimated efficiency loss of $7.2 billion. The tax-interaction effect is also moderately larger than for the previous policy, at $29.7 billion, because of the income effect on labor supply from cash transfers, which further reduces efficiency, given that leisure is a normal good. Overall, the policy costs $45.1 billion, or $90.7 per ton of CO_2 reduced, which is 5.5 times the standard estimate of cost.

Effectively, a cap-and-trade policy that does not use the rents to cut distortionary taxes can be thought of as two separate policies. One puts a price on CO_2 emissions, and the other creates a new government spending program (a system of dividend payments) that comes at the opportunity cost of higher distortionary taxes. The latter component comes at a considerable efficiency cost. For the remaining policies, we made our own approximations of the revenue-recycling and tax-interaction effects (see the Appendix).

Market-based policy applied to the electricity sector only. The potential revenue-recycling effect under a market-based policy applied just to the power sector is much smaller ($15.1 billion) compared with an economy-wide policy, for the same (economy-wide) reduction in CO_2 emissions. This reflects the much smaller base of the CO_2 tax (or auctioned allowance system), which applies to 2 billion tons of CO_2 emissions remaining from the power sector in

2020, compared with a base of 5.4 billion tons under an economy-wide policy. However, a partially offsetting factor is that a higher tax rate ($37.2 per ton) is needed under the sectoral policy to meet the same economy-wide emissions reduction.

The tax-interaction effect is also smaller ($10.9 billion) under an electricity-only policy that exploits the revenue-recycling effect. This is because the sectoral policy has a weaker impact on the general price level: the pass-through of tax revenue and compliance costs (measured by the standard approach) increases the general price level by only about half as much as under its economy-wide counterpart. The overall result is a welfare cost of $5.1 billion, or $10.3 per ton of CO_2 reduced, for a market-based policy exploiting the revenue-recycling effect.

For a power sector–only policy that does not exploit the revenue-recycling effect, overall policy costs are estimated at $25.6 billion, or $51.5 per ton of CO_2 reduced. This policy is actually *less* costly than its economy-wide counterpart. Although it fails to optimally exploit emissions reductions across sectors, this disadvantage is more than offset by the smaller tax-interaction effect compared with economy-wide pricing.

Emissions standard. The overall cost of the emissions standard for the power sector is estimated at $29.2 per ton of CO_2 reduced—substantially lower than the market-based policy with no revenue-recycling effect, regardless of whether the latter policy is applied economy-wide or to the power sector only. Since the emissions standard creates no scarcity rents, it has a very small effect on the general price level compared with market-based policies, and consequently the emissions standard causes a much smaller loss ($1.9 billion) from the tax-interaction effect.

Summary

Our intuition about the inevitable superiority, on cost-effectiveness grounds, of economy-wide, market-based approaches to reducing CO_2 emissions appears to break down when we take into account inevitable interactions between policies and the broader fiscal system, at least for the scale of emissions reduction considered here. A big problem with market-based approaches is that they generate large revenues or rents—the more so the more comprehensive the policy. If these revenues or rents are not used to increase economic efficiency, it is quite possible that sector-specific policies and nonregulatory approaches are superior on cost-effectiveness grounds. In fact, the economy-wide cap-and-trade policy without the revenue-recycling effect performs the worst of all the policies considered in Table 1.

Figure 4 underscores the point. Here we consider net benefits—that is, climate change benefits less welfare costs. There is much dispute about the appropriate value to place on CO_2 to reflect future global warming damages—or the social cost of carbon (SCC)—because this value is sensitive to uncertain future impacts and assumptions about long-range discounting. A thorough interagency review (U.S. IAWG 2010) recommended that regulatory analyses use SCC values of \$6.8, \$26.3, and \$41.7 per ton of CO_2 (for year 2020 in 2007 dollars), depending on assumed discount rates, as well as a value of \$80.7 to capture the possibility of extreme damage outcomes. For the sake of argument, in Figure 4 we assume that our emissions price, \$33 per ton, reflects the SCC (for year 2020), implying benefits of \$17.8 billion from the emissions reduction in 2020.

Under this assumption, the economy-wide, market-based policy with revenue recycling (RR in the figure) generates the largest annual net gain, \$20.9 billion, given that it has a negative cost. Also welfare improving, but on a much smaller scale, is the market-based policy with revenue recycling, applied to the power sector only. It generates a net gain of \$11.3 billion. The emissions standard for the power sector breaks even, with net benefits of \$1.9 billion.[10] On the other hand, the market-based policies without revenue recycling generate overall welfare losses, from \$9.2 billion for the electricity-only policy to \$28.7 billion for the comprehensive policy. For these policies, the welfare gains from correcting the carbon externality are more than offset by the cost of the tax-interaction effect. In fact, the economy-wide pricing policy without revenue recycling is welfare *reducing* unless the social damage from CO_2 is (well) above \$90.7 per ton.

4. Reasons to Be Cautious?

There are many reasons to be suspicious of those provocative findings, which seem to overturn conventional wisdom on the necessary superiority of broad, market-based approaches. Here we take up some possible counterarguments relating to policy stringency, the reliability of revenue-recycling and tax-interaction effect estimates, other behavioral responses to emissions pricing, policy-induced technological innovation, ancillary benefits, distributional considerations, and the promotion of international climate agreements.

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[10] Although this policy has a relatively small tax-interaction effect, its welfare potential is undermined because it is too stringent. The marginal cost from the last ton reduced, as measured by the standard approach, is \$51.8 per ton, well above the assumed \$33 benefit per ton.

Policy stringency. It is straightforward to see that the relative importance of the revenue-recycling effect under the economy-wide, market-based policy declines at higher levels of abatement. Although the height of the rectangle representing carbon tax revenue in Figure 2(c) increases with more abatement, its base declines, and indeed, beyond some point (corresponding to the peak of the Laffer curve), marginal tax revenue turns negative. In contrast, both the height *and* the base of the triangle under the MC^{ALL} curve increase with greater abatement. How sensitive are the relative cost-effectiveness rankings of different instruments to the scale of medium-term emissions reductions?

To provide some broad sense for this, we consider a policy that is twice as stringent as in the previous case, reducing domestic CO_2 emissions by 17 percent in 2020. Given our linearity assumptions, this emissions reduction would require an emissions price that is twice as high ($66 per ton) as before. We also assume that the share of those reductions coming from different sources (e.g., fuel switching) remains the same.

The second set of rows in Table 2 summarizes the results. Average costs per ton reduced under the different policies are twice as high, according to the standard approach. In contrast, the proportionate increase in the revenue-recycling effect is smaller—79 percent for the economy-wide policy and 43 percent for the sectoral policy—while the proportionate increase in the tax-interaction effect is 78 to 91 percent for the pricing policies.[11] Nonetheless, the relative ranking of different policies, as measured by their cost-effectiveness, remains unchanged. The economy-wide pricing policy with revenue recycling is still the most cost-effective policy, at $13.7 per ton of CO_2 reduced, while without revenue recycling this policy is the most costly, $104.1 per ton. The second most efficient policy, the pricing instrument for the power sector with revenue recycling, costs $35.0 per ton. So even under this more aggressive emissions reduction scenario,

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[11] Note that a given economy-wide emissions reduction has a much greater proportionate effect on reducing the base of the sectoral tax than the economy-wide tax. Hence the smaller proportionate increase in the revenue-recycling effect under the sector policy.The tax-interaction effect depends on the increase in energy prices, which reflects both policy rents and costs measured by the standard approach. Therefore, it increases at a faster rate than the revenue-recycling effect with greater abatement.

the economy-wide pricing policy with revenue recycling still has a large advantage over all the other policies.[12]

Further thoughts on estimates of fiscal linkages. The Parry and Williams estimate of the MEB is based on calculations of income, payroll, and sales tax rates (computed from the TAXSIM model of the Natural Bureau of Economic Research) for households disaggregated into five income groups, as well as evidence on behavioral responses to tax changes. The latter comes from estimates of the taxable income elasticity, which takes into account how changes in labor supply and shifting toward tax-favored spending reduce revenue in response to higher tax rates. Parry and Williams (2010) assume an average value of 0.29 for this elasticity.[13] Based on a careful review of the latest evidence, Saez et al. (2009) suggest that a plausible range of values for this elasticity is 0.12 to 0.40, which would imply the MEB lies between about 0.10 and 0.40 (using the Parry and Williams spreadsheets). Even under the lowest value for the MEB, however, the relative ranking of policy instruments in Table 2 would be unaffected.

How about the tax-interaction effect? Given that climate policies reduce real wages only by a very small amount, is it reasonable to assume any labor supply effect at all? Labor supply clearly responds to large real wage changes, so an issue is whether the wage changes must exceed some threshold before there is any response. Although workers may not respond immediately to every little change, they will respond on average over the long run. Any discontinuities are likely to be heterogeneous across workers, however: for any particular change, some workers will ignore it, while for others it will push them past some threshold and induce a relatively large response. Averaged across the entire workforce, therefore, aggregate labor supply should closely approximate a continuous response.

Underpinning our calculations of the tax-interaction effects are assumptions that energy-intensive goods exhibit the same degree of substitution with leisure as consumption goods in general and that the burden of climate policies is fully passed forward into higher energy prices. For a first approximation, both assumptions seem reasonable. Given that energy is used

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[12] At much higher emissions reduction levels still, the relative cost differential between market-based policies that do and do not exploit the revenue-recycling benefit will eventually become far less pronounced, and the superiority of (traditional) cap-and-trade approaches over sectoral and regulatory approaches is likely restored (e.g., Goulder et al. 1999). But emissions reductions of this scale are not envisioned until well into the future.

[13] They assume the elasticity is greater for higher-income households, who have more access to avoidance opportunities, including deductible expenses.

pervasively in the production and use of consumer goods in general, the average leisure substitute assumption seems plausible (in the absence of empirical evidence to the contrary), and even in states that retain cost-of-service regulation, higher fuel prices will be passed forward into electricity prices.

One caveat here is that electricity generation is complex because it involves multiple technologies. Since prices are frequently set by natural gas generation (which is often the marginal technology), some of the burden of higher fuel prices may come at the expense of rents earned by inframarginal, previously sunk investments in coal generation, rather than being fully passed through into higher generation prices. In turn, this implies a weaker tax-interaction effect. However, this is likely a temporary phenomenon: because carbon pricing is built into expectations about future fuel prices, new investment will shift away from carbon-intensive but lower-cost generation, with a resulting increase in average generation prices.

Emissions reductions by source. In the above calculations for economy-wide emissions pricing, the very high proportion of CO_2 reductions that come from the power sector keeps down the loss of cost-effectiveness of policies that exploit reductions from the power sector only. In practice, it is possible that fewer reductions will come from the power sector if, for example, there are practical obstacles to the expansion of nuclear (because of safety concerns) and wind power (because of opposition to transmission lines from remote generation sites). On the other hand, oil use may be more responsive to emissions pricing under more optimistic scenarios for the future availability and cost of fuel-saving technologies.

For the sake of argument, suppose that economy-wide CO_2 reductions in response to emissions pricing are the same as above, but that a smaller portion of those reductions comes from the power sector and a correspondingly larger portion comes from the transport and other sectors.[14] The third set of rows in Table 2 assumes that reductions from the transport and other sectors are 2.5 times as large as assumed above, implying the shares of reductions from the power sector are 72 rather than 89 percent. Under these assumptions, costs under all three sectoral policies are higher. For example, according to the standard approach, costs under the emissions standard would be 81 percent higher than under economy-wide pricing. However,

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[14] Other models project economy-wide emissions-pricing responses that are broadly consistent with those assumed above. See, for example, Paltsev et al. (2007), U.S. EPA (2008), and CRA International (2008).

accounting for fiscal linkages, the relative ranking of policies is unaffected, at both the 8.5 and the 17.0 percent emissions reduction, with the market-based, economy-wide policy with no revenue recycling having the highest cost per ton reduced.

Incentives for clean technology innovation. Our discussion above does not consider the effect of policies in promoting the development of cleaner production technologies over the longer run, thereby lowering future abatement costs and increasing the emissions reduction implied by a given emissions price. In fact, market-based approaches are thought to have an efficiency advantage over regulatory approaches in that they can provide more effective incentives for such technology development. For our purposes, the question is whether this consideration would substantially affect our relative policy rankings.

Although this is an extremely complicated issue, Parry et al. (2003) at least provide a starting framework for understanding how the (discounted) welfare gains from emissions pricing policies increase with the amount of induced innovation under different scenarios for discount rates, the initial level of abatement (assumed to internalize the emissions externality), and the speed with which induced innovation lowers future marginal abatement costs. The speed of innovation cannot be projected with any accuracy, but to us a reasonable guesstimate is that it will take perhaps 20 to 40 years for induced innovation to cut abatement costs in half (relative to a case with no induced innovation), for the approximate scale of emissions-pricing policies that are being considered for 2020 and beyond. Under these conditions, Parry et al. (2003, Table 1), estimate that induced innovation increases the long-run welfare gains from emission pricing—as measured by the standard approach—by perhaps 15 to 90 percent relative to the case with no innovation (for a 5 percent social discount rate). Even if the emissions standard and sectoral policies provided much weaker incentives for clean-technology innovation than economy-wide pricing policies (which is questionable), this order of magnitude for additional welfare gains from induced innovation is not sufficient to overturn the qualitative ranking of policy instruments, at least according to Figure 4: the welfare gain calculated under the standard approach amounts to $8.2 billion under the economy-wide pricing policies.

Ancillary benefits. What about ancillary benefits due to reductions in noncarbon externalities in the energy sector? Again we provide only a cursory discussion, being careful to also consider preexisting policies directed at these externalities.

Especially tricky in the latter regard is the possibility of ancillary health benefits in the power sector. If sulfur dioxide (SO_2) emissions, the major source of mortality risk from particulates, are fixed by a binding cap, any ancillary health effects might be very small (there could be some effect if changes in the fuel mix in response to carbon policy reallocate the spatial pattern of SO_2 emissions across regions with different population exposure). To what extent SO_2 will remain capped in the eastern United States if the Clean Air Interstate Rule is replaced by the proposed Transportation Rule (see U.S. EPA 2010), with carbon pricing placed on top, is somewhat unclear, however. Based on a compromise value, we assume ancillary benefits in the power sector of $12 per ton of CO_2 reduced (see Appendix).[15]

Ancillary benefits from reductions in automobile travel include reduced externalities from traffic congestion, traffic accidents, local pollution, and road damage. We put ancillary benefits at $1.28 per gallon of gasoline reduced in 2020, or $145 per ton of CO_2, after netting out preexisting fuel taxes (see Appendix).

To the extent that policies reduce CO_2 from autos (and other transportation vehicles with comparable external costs), they provide much greater ancillary benefits than CO_2 reductions from the power sector. Assuming (based on Krupnick et al. 2010) that 5 percent of the economy-wide CO_2 reductions comes from autos under economy-wide pricing, ancillary benefits would be $9.6 billion under those policies in 2020 compared with $6.0 billion under the sectoral policies (when the economy-wide CO_2 reduction is 8.5 percent). Thus, inclusion of these ancillary benefits does not alter our earlier result, that economy-wide cap-and-trade has the highest welfare costs and is welfare reducing under our assumed value for the SCC. The reason is that the effect on the auto sector is just too small.[16]

Distributional considerations. Clearly, from a global perspective, carbon policy in the United States is progressive, since the future beneficiaries of slowed global warming are disproportionately located in lower-income, climate-sensitive countries. Nonetheless, within the

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[15] At first glance, it might be thought that indirect health improvements from carbon policy might counteract the tax-interaction effect, to the extent that workplace productivity improves. However, as discussed in Williams (2002), health benefits coming primarily from reduced mortality (as is the case here) are best modeled as an increase in households' lifetime time endowment. This causes an income effect but not a substitution effect because it does not increase the marginal value of work time relative to leisure. Under these conditions, health effects have little or no consequence for the tax-interaction effect.

[16] The above discussion has captured what we believe are the main sources of preexisting distortion that might be important for the welfare effects of U.S. climate policies. Another possible distortion of significance is nonmarginal-cost pricing in the power sector, but it can be difficult to make definitive statements even about the sign, let alone the magnitude, of the price–marginal cost gap, when averaged across region and time of day. Yet another possibility is consumer undervaluation of energy efficiency due to myopia or other factors, though evidence on whether there is a significant market failure in this context remains mixed (e.g., Greene 2010; Helfand and Wolverton 2009).

United States, carbon policies are regressive, given that lower income households have relatively larger budget shares for electricity and energy-intensive goods, even when income is measured on a lifetime basis (e.g., Metcalf 2009). There are several perspectives on this issue.

One approach is to account for distributional effects by applying social welfare weights to the costs of environmental policies for different income groups (e.g., Cremer et al. 2003). The problem here is that the choice of welfare weights is arbitrary and may have a considerable effect on the magnitude of estimated welfare costs.[17]

Another view is that the broader tax (or benefit) system should be adjusted, insofar as possible, to keep the overall burden of climate policy distribution neutral (e.g., Kaplow 2004; Metcalf 2009). This could be achieved through a somewhat bigger reduction in tax rates for lower-income groups and a somewhat smaller reduction for higher-income groups, to offset the regressive effects of higher energy taxes. The efficiency gains from the revenue-recycling effect would be smaller in this case (compared with equal proportionate reductions across all households).[18] For example, Parry and Williams (2010) estimate that distribution neutrality would reduce the revenue-recycling effect by about a third for the scale of emissions pricing discussed above for 2020 (and when lifetime household income is proxied by annual household expenditure).

The practical feasibility of distribution-neutral policy changes might also be questioned. Logically, adjustments to the tax system would be required every time a policy is introduced, or changed, to address any (environmental or other) market failure. We might even question whether too much attention is paid to distributional issues. After all, it is very difficult to counteract the numerous, constantly changing market forces that affect the relative wages for different occupations and regions. In fact, once tax preferences are taken into account, the U.S.

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[17] Welfare weights might be inferred from observed trade-offs between efficiency costs and distributional incidence made in other government decisions. However, these estimates may be an unreliable indicator of society's true preferences, given that policy decisions are, at least in part, the outcome of interest group competition rather than entirely the result of benevolent government optimization.

[18] An incremental reduction in marginal rates for lower-income groups causes a smaller efficiency gain than that from an incremental reduction in marginal rates on higher-income households. One reason is that lower-income groups face smaller tax wedges and are also less responsive to changes in tax rates, given they have fewer opportunities for exploiting tax preferences. Another is that cutting tax rates on low-income groups is expensive in terms of revenue outlays, given that all higher-income groups will also benefit from the rate reduction for the lower-income bracket.

tax system does not look very progressive, nor does the public spending side, given large middle-class entitlements (e.g., Pechman 1986). Some economists recommend that policymakers focus less on distributional incidence and more on targeted educational, health, and other policies to promote social mobility and lift people out of poverty (e.g., Harberger 2003). In short, it might be argued that pricing externalities and poverty alleviation are distinct goals, requiring completely different instruments whose designs should be kept separate rather than confounded.[19]

Promotion of international agreements. Credible, comprehensive action by the United States to reduce GHGs could well have a knock-on effect in other countries. For example, the European Union has pledged stiffer emissions control targets for 2020 should other countries take comparable steps, and at present U.S. inaction provides an excuse for poorer countries to delay costly mitigation programs.

Leaving aside complications posed by emissions leakage (i.e., the possibility that emissions elsewhere rise in response to lower fuel prices) or capital flight (a possible result of U.S. mitigation policy), should a multiplier be applied to the benefits of U.S. reductions, representing follow-on action by other countries?

If welfare is being viewed from a domestic perspective, then yes, to the extent that other countries take action as a result of U.S. policy, and that action has benefit for the U.S. economy, applying some multiplier to benefits would be appropriate. However, in this case a domestic value for the SCC should be used in computing domestic welfare effects. Given that the domestic SCC is valued at only about 7 to 23 percent of the global SCC (U.S. IAWG 2010, 11), the benefit of the policies discussed above would likely be smaller under this approach.

If, on the other hand, the more common global welfare perspective is taken, applying any multiplier to the benefit of U.S. emissions reductions is tricky because abatement costs to other countries should also be taken into account in assessing any value for the multiplier. As we have

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[19] There is some confusion about whether distributional issues might negate some of the earlier results on the net effect of fiscal linkages. Kaplow (2004) suggests (implicitly) that the revenue-recycling and tax-interaction effects wash out at the margin in a model that has only labor tax distortions and distinguishes among household income groups. However, this result relies on a set of restrictive assumptions about individual preferences, and Williams (2009) shows that an equally plausible alternative set of assumptions leads to results that match those from earlier models that ignored distributional issues. Thus, this issue is not one that can be settled with theory alone; it remains an open empirical question.

seen, measuring abatement cost is complicated and can be very sensitive to specific policy details, especially when climate policies interact with preexisting distortions in an economy.

In short, although the discussion in this section highlights some nuances (e.g., when policymakers are concerned about distributional impacts), it is hard to escape the general conclusion that carbon tax shifts (or their auctioned-permit equivalent), with revenues used to cut other taxes, may be the only economically sound instrument for achieving medium-term targets for U.S. CO_2 reductions.

5. Conclusion

The revenue or rent created by market-based climate policies is potentially problematic. Ideally, it should be used to substitute for distortionary taxes (or otherwise increase economic efficiency) so that we can be confident that economy-wide carbon policies improve welfare and are significantly more cost-effective than sectoral pricing policies or (smart) regulatory instruments. The best way to do this is to design a carbon tax as part of the broader fiscal system whose overall purpose is to meet a sequence of government revenue targets over time. In fact, a carbon tax of the scale examined here could not be more timely. It would simultaneously kick-start a serious program to ratchet back carbon emissions in the United States, and thereby remove a major impediment to wider global participation in mitigation efforts, while substantially reducing the nation’s projected budget deficit (and the need to raise other taxes) out to 2030.

In principle, cap-and-trade systems can be designed to mimic any advantage of a carbon tax, most notably through full allowance auctions. However, even if all allowances were auctioned, legislators responsible for designing cap-and-trade systems may be reluctant to hand over the entire proceeds to the Treasury. Cap-and-trade systems that do not use the rents to cut distortionary taxes are best viewed as combining two policies: a price on carbon, plus an increase in (transfer or other) government spending financed through higher distortionary taxes. The latter component can greatly undermine the overall cost-effectiveness of the program for envisioned CO_2 reductions over the medium term. Pricing policies or emissions standards focused on the power sector alone perform better than economy-wide cap-and-trade (without the revenue-recycling benefit), but they are distinctly more costly than carbon tax shifts.

It is entirely fair to point out that revenues raised under a carbon tax might not be used to increase economic efficiency. In fact, some evidence suggests that in the past, U.S. governments have spent windfall revenues rather than used them to cut other taxes (e.g., Becker and Mulligan 2003), which may not have always generated efficiency gains comparable to those from cutting other taxes. Alternatively, exemptions to politically influential industries might be granted under a carbon tax, eroding its cost-effectiveness. The case for the carbon tax (or auctioned permits) over other instruments hinges critically on the accompanying legislation requiring offsetting reductions in other taxes (or avoiding tax increases that would otherwise be enacted to meet deficit reduction objectives).

We should always be cautious in taking the policy implications from economic models too literally: our judgment about reasonable parameter assumptions can change, there is always the possibility that models have missed something important, and policymakers may be concerned about criteria other than economic efficiency. Nonetheless, based on the evidence as we see it, there seems to be a solid case on economic grounds for moving ahead with carbon tax shifts in the United States, in preference to any other climate policy instrument.[20]

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[20] For further discussion of the advantages of carbon taxes over cap-and-trade systems, see Nordhaus (2007).

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Appendix

Ancillary Benefits from Reducing CO_2 Emissions from the Power Sector

As noted above, ancillary benefits from possible SO_2 reductions, as other fuels are substituted for coal and the overall scale of electric generation declines, are somewhat speculative because they depend on the extent to which SO_2 remains capped through other regulations. As a result, ancillary benefits at present might be anything from essentially zero to around $40 per ton of CO_2.[21] We split the difference for a compromise value of $20 per ton.

To update this figure to 2020, we should increase it to reflect increased population growth and exposure to pollution, as well as greater willingness to pay for mortality risk reductions as a result of higher real income per capita. In Krupnick et al. (2010), real GDP (reflecting both of these factors) is projected to expand by about a third between now and 2020. On the other hand, the figure should be scaled back to reflect reductions in power sector SO_2 emissions in the business-as-usual case, with no climate policy. In fact, SO_2 emissions fall in this case by 55 percent as the dirtiest plants are retired over time. As a result of these factors, we assume a value of $12 per ton for SO_2 benefits in 2020.

Ancillary Benefits from Reducing Gasoline

For automobiles, Parry (2010) assumes local pollution damages, marginal congestion costs, and accident externalities of 1.0, 4.5, and 3.0 cents per vehicle mile, respectively, for 2007. Following Small (2010), we update the congestion and accident externalities for 2020 to 5.5 and 3.6 cents per mile, assuming they grow in real terms at 1.5 percent a year. Multiplying combined externalities (10.1 cents per mile) by on-road fuel economy, assumed to be 25 miles per gallon in 2020 (from Krupnick et al. 2010), gives $2.53 per gallon. We then scale this back by a third, based on the assumption that two-thirds of the fuel reduction comes from reduced vehicle miles (one-third comes from improved fuel economy, which has no ancillary benefits). Finally, we net out preexisting gasoline taxes (taken to be the same in real terms in 2020 as at present, 40 cents per gallon), to leave ancillary benefits of $1.28 per gallon. Dividing by CO_2 per gallon of gasoline (0.0088 tons) gives benefits of $145 per ton of CO_2.

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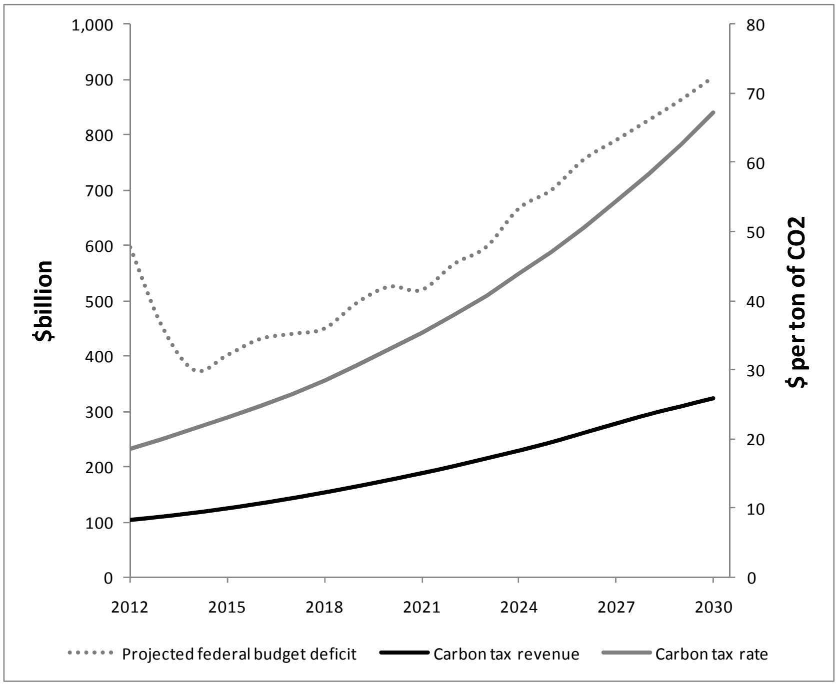
[21] This is based on a preliminary assessment by Nicholas Muller (personal communication, September 2010).

Figures and Tables

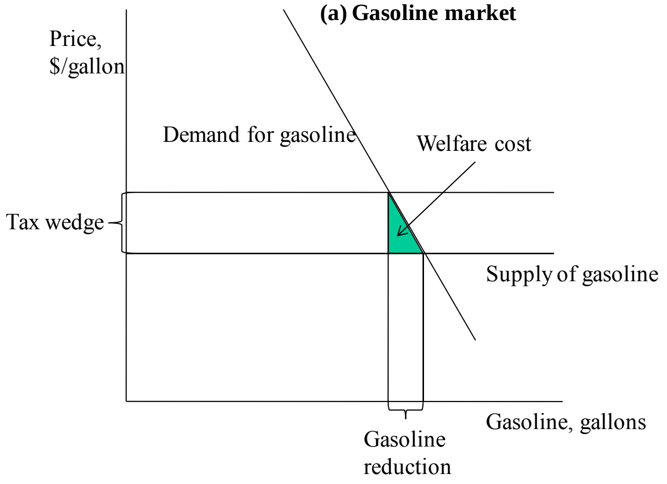
Figure 1. Potential Contribution of Carbon Tax to Future Deficit Reduction (all figures in 2007$)

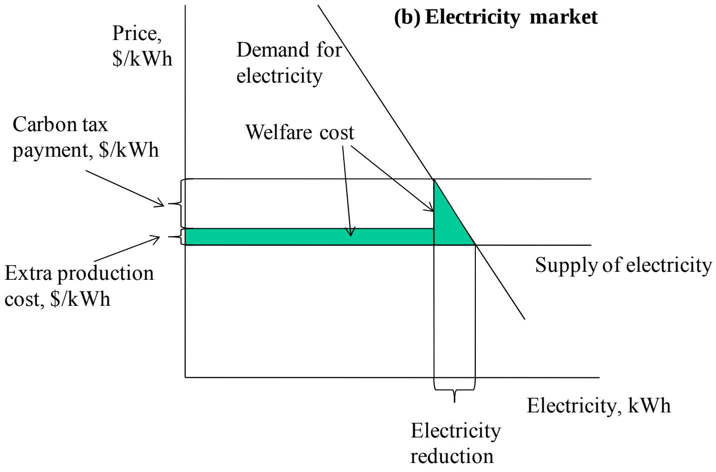


Sources: Deficit projections from CBO (2010). Carbon tax and revenue projections from spreadsheets developed by Krupnick et al. (2010).

Note: Carbon tax path is chosen to replicate the projected price on CO_2 emissions (in 2007$) in Krupnick et al. (2010) that would have been forthcoming under recent climate legislation with an intermediate assumption about the availability of emission offsets (see Section 2).

Figure 2. Welfare Costs of Carbon Tax
(with no prior taxes and other externalities)


(a) Gasoline market


(b) Electricity market

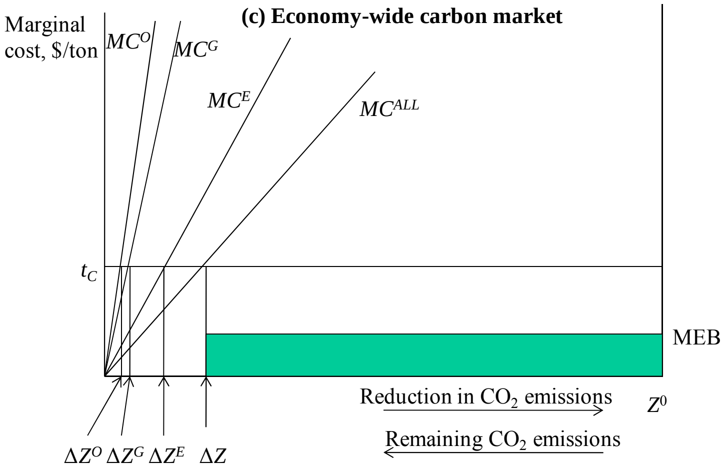

(c) Economy-wide carbon market

Figure 3. Welfare Cost of Labor Tax Distortions

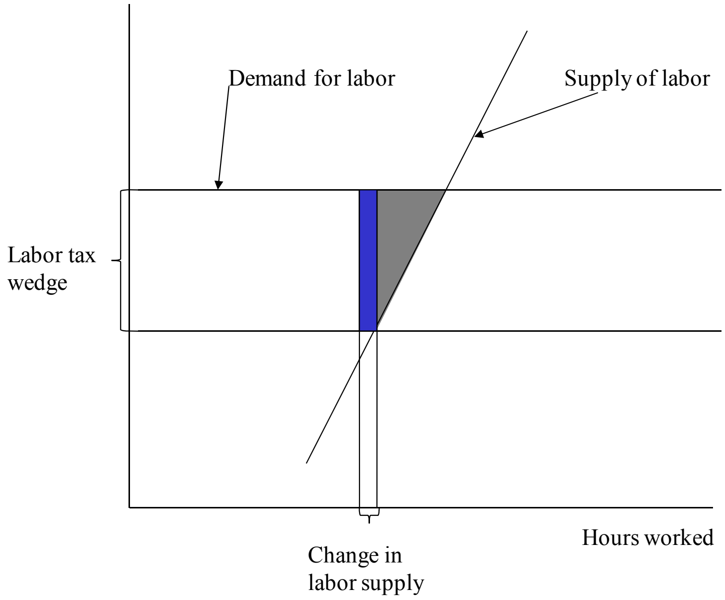


Figure 4. Net Benefits of 8.5% Reduction in CO_2 in 2020 (billion 2007$)

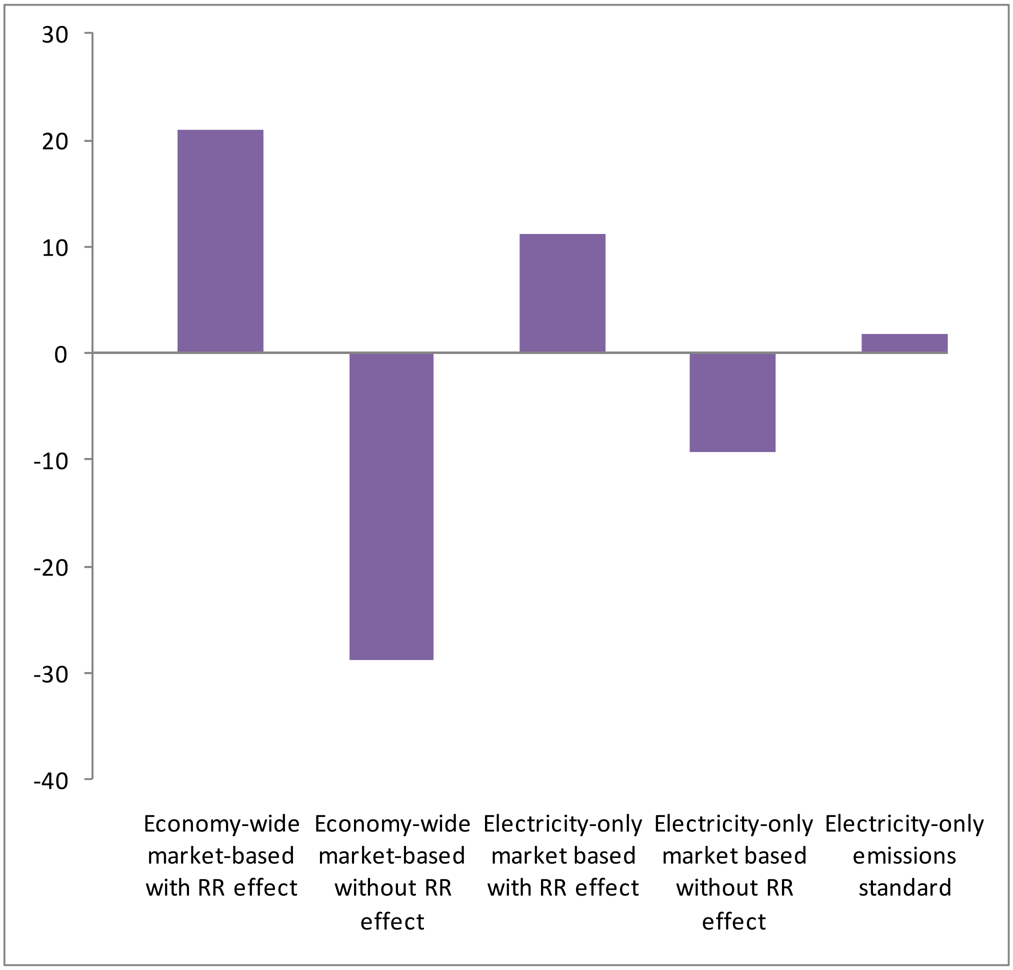


Table 1. Benchmark Data Assumptions for Year 2020

Data	no-policy baseline	CO_2 reduction of 8.5% relative to baseline
Emissions data for economy-wide pricing policy		
Economy-wide CO2 emissions, billion tons	5.88	5.38
Power sector emissions, billion tons	2.46	2.02
Electricity sales, billion kWh	4,125	3,937
Fraction of economy-wide CO2 reduction from power sector	na	0.89
Fraction of economywide CO2 reduction from fuel switching	na	0.68
CO2 prices or shadow prices, $ per ton		
Economy-wide policy	na	33.0
Electricity-only policy	na	37.2
Emissions standard	na	48.7
Revenue/rents from pricing policies, $billion		
Economy-wide policy	na	178
Electricity-only policy	na	73.1
General increase in price level relative to economy-wide pricing policy		
Electricity-only pricing policy	na	0.44
Emissions standard	na	0.07
Revenue needed to maintain transfers in real terms following higher energy prices, $billion		
Economy-wide market-based policy	na	29.0
Electricity-only market-based policy	na	12.8
Emissions standard for the power sector	na	1.9
Marginal excess burden of income taxation	na	0.25

Source. Krupnick et al. (2010), Parry and Williams (2010).
Note. All monetary figures are in year 2007 dollars.

Table 2. Welfare Cost Estimates for Reducing CO_2, 2020

(Year $2007)

Policy instrument	Market-based				Emissions standard
Sectoral coverage	Economy-wide		Power sector		Power sector
Revenue/rents allocated to	cutting distortionary taxes	lump-sum transfers	cutting distortionary taxes	lump-sum transfers	
8.5 percent reduction in CO2					
Standard Approach					
Total welfare cost, $billion	8.2	8.2	9.2	9.2	12.1
Average cost, $ per ton	**16.5**	**16.5**	**18.6**	**18.6**	**24.4**
Accounting for Fiscal Interactions					
Revenue-recycling effect, $billion	-37.4	7.2	-15.1	3.2	0.5
Tax-interaction effect, $billion	24.7	29.7	10.9	13.2	1.9
Total welfare cost, $billion	-4.5	45.1	5.1	25.6	14.5
Average cost, $ per ton	**-9.1**	**90.7**	**10.3**	**51.5**	**29.2**
17.0 percent reduction in CO2					
Standard Approach					
Total welfare cost, $billion	32.8	32.8	37.0	37.0	48.4
Average cost, $ per ton	**33.0**	**33.0**	**37.2**	**37.2**	**48.7**
Accounting for Fiscal Interactions					
Revenue-recycling effect, $billion	-66.8	13.9	-21.6	5.7	1.9
Tax-interaction effect, $billion	47.2	56.8	19.4	23.4	7.7
Total welfare cost, $billion	13.2	103.4	34.8	66.0	58.1
Average cost, $ per ton	**13.3**	**104.1**	**35.0**	**66.4**	**58.4**
Lower share of reductions from the power sector					
8.5 percent reduction in CO2, average cost, $ per ton					
Standard approach	16.5	16.5	22.8	22.8	29.8
With fiscal interactions	-9.1	90.7	12.6	63.1	35.8
17.0 percent reduciton in CO2, average cost, $ per ton					
Standard approach	33.0	33.0	45.5	45.5	59.7
With fiscal interactions	13.3	104.1	42.8	81.3	71.5

Sources. See text.